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VALIDITY OF AGE DETERMINATION FROM SCALES OF MARKED AMERICAN SHAD

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ABSTRACT

In the fall of 1952, one hundred thousand juvenile American shad, marked by removal of the right pelvic fin, were released in the Connecticut River. Seventeen marked fish were recovered in the river in 1956, 70 in 1957, and 39 in 1958. Ages of the fish, determined from their scales, were 4, 5, and 6 years, respectively. These findings were in agreement with known age established from marking and therefore validate annuli and spawning marks as criteria for age determination of shad.

VALIDITY OF AGE DETERMINATION FROM SCALES OF MARKED AMERICAN SHAD

By MAYO H. JUDY, *Fishery Research Biologist,*
Bureau of Commercial Fisheries

In 1950, the U.S. Fish and Wildlife Service, as e primary research agency of the Atlantic States arine Fisheries Commission, began a study of e American shad (*Alosa sapidissima*) on the Atntic coast of the United States. Objectives of is investigation were to determine the causes for ecline in the commercial yield from approxnately 50 million pounds in 1896 to 8 million ounds in 1950, to determine conditions favoring covery, and to provide information for scientific anagement of the fishery. A necessity for acmplishing these objectives was an accurate ethod of aging shad.

Prior to this investigation, techniques for aging ad had been presented by various workers. eim (1924) determined age by means of winter ngs or annuli on scales and established the relaon between scale and body length. Borodin 925) presented a method of reading scales by unting the number of transverse grooves and viding by 2 to determine the age in years. Bary (1925) found evidence in otolith markings to dicate that age estimates as reported by Borodin ere correct, but Greeley (1937) stated that Boron's method gave misleading results. Greeley und that Leim's method of age determination reed with the results of his studies on Hudson iver shad.

Cating (1953) proposed a method for reading ad scales for total age, age at first spawning, d number of times the fish had previously awned. Transverse groove counts were used to parate true from fasle annuli to the fourth anlus, and age of fish spawing for the first time as determined by counting the number of anli and adding 1 year for the scale edge. Age fish spawning for the second or more times was obtained by counting the number of annuli plus the number of spawning marks and adding 1 year for the scale edge.

Although Cating aged shad with apparent confidence he did not establish the validity of his readings. LaPointe (1958), using Cating's method, validated the annulus to be a true year mark on scales of fish spawning for the first time. He found that Leim mistook the fresh-water mark for the first annulus, thus causing a difference of 1 year between Leim's age determination and those in his study. Hammer (1942) confirmed that the fresh-water zone was a distinct and measurable scale growth formed while juveniles are in fresh water.

In 1952, prior to the completion of Cating's scale study, a marking program was conducted on juvenile shad in the Connecticut River. The objective of this program was to recover in future years marked fish of known age, thereby to check the method employed by Cating and to establish a correct method for aging shad from their scales. This was deemed necessary because techniques used prior to this time were subject to question.

Data presented in this paper were derived from the scales of marked adult shad recovered 4, 5, and 6 years following the marking program. Scales from these fish of known age were studied to determine the validity of annuli and spawning marks for age determination.

Appreciation is expressed to the Connecticut Power and Light Company for use of the Windsor Locks Canal System, and to the shad fishermen and fish dealers of the Connecticut River for their cooperation in this study.

LIFE HISTORY

Shad range on the Atlantic coast from the St. Johns River in Florida to the St. Lawrence River in Canada. It is an anadromous fish and spawning migrations begin as early as November in

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Florida and as late as June in Canada. The young remain in the rivers until fall, attaining lengths from 3 to 5 inches, then migrate to sea. Winters are probably spent off the Middle Atlantic, and summer and fall in the Gulf of Maine. After reaching maturity, in 3 to 6 years, they return to the rivers to spawn. Adult shad native to streams north of Cape Hatteras (N.C.) that survive spawning and other hazards return to the sea and re-enter the rivers to spawn again in successive years. Shad native to streams south of Cape Hatteras die after spawning (Talbot and Sykes, 1958).

MATERIALS AND METHODS

In the fall of 1952, 100,000 downstream migrant juvenile shad were marked on the Connecticut River in the Windsor Locks Canal, Windsor Locks, Conn. Marking of these fish, which averaged about 4 inches in fork length, was accomplished by clipping the right pelvic fin close to the body of the fish. Juveniles were trapped, seined, and marked in one level of the canal and then placed in a lower level of the canal and flushed into the main river. Samples of fish were held overnight to obtain an estimate of mortality. Mortality from marking was estimated at 30 percent; therefore, it was assumed that 70,000 marked juveniles were returned to the river.

The first marked fish were recaptured in the Connecticut River in 1956 from commercial catches and shad passed by the fishway at Hadley Falls Dam, Holyoke, Mass. Subsequent recoveries were made in 1957 and 1958 from commercial and sport catches. Approximately 35,000 shad were examined annually. From the 1956 collection it was determined that some shad had malformed, or naturally missing, pelvic fins. Therefore, in 1957, fish with various pelvic fin abnormalities were collected so that a wide assortment of abnormal fins would be available for comparison with marked fins. The pelvic girdle section of each fish collected was removed, labeled, and preserved. In addition, scale samples were taken and the length, weight, and sex recorded.

EXAMINATION OF SCALES

Two scales from each fish collected were impressed in plastic, using a modification of the method described by Greenbank and O'Donnell (1950). The scale impressions were read on a Eberbach projector, by two biologists using Ca ing's (1953) method for determining age of sha Age readings were compared and the resul confirmed.

In this method the scale edge is counted as a yea mark because the last annulus (near scale peripl ery) is frequently eroded during the spawning m gration. For example, a shad spawning for th first time (virgin fish) at 4 years of age has 3 annu on the scale plus the scale edge for a total age c 4 years. After shad spawn and return to the se renewed feeding and resumption of growth leav a characteristic scarlike mark on the scale edg where erosion occurred during the spawning m gration (Moss, 1946). This is designated as spawning mark and is used in place of the erode annulus, formed prior to spawning, for determin ing age of "repeater" fish (those spawning fo the second or more times). For example, a 6-yea old repeater spawning for the second time has annuli and 1 spawning mark which, when read t include the scale edge, gives a total age of 6 year The 4 annuli and 1 spawning mark indicate tha this fish first spawned at 5 years of age and was o its second spawning run when captured.

EXAMINATION OF PELVIC FINS

Examination of the pelvic fin sections indicate that they contained malformed, missing, an marked fins. Malformed and missing fins ar often found in fish as evidenced from studies b Cable (1956), Code (1950), and Rich and Holme (1928). Marked fins were characterized by varied pattern of fin regeneration ranging from n regeneration beyond formation of scar tissue t almost complete, but distorted regeneratio These findings are not unusual since, as reporte by Stuart (1958), fin clipping seldom results in uniform series of marks. From microscopi examination of regenerated marked fins, Stuar found that new growth of fin rays does not exten in a regular manner but commences as a thickene and undifferentiated cap, the connective and othe tissues keeping pace with the growth of the adja cent rays. The degree and nature of fin regenera tion was usually dependent on the angle of the cu and the amount of dermal-fin-ray tissue remove during clipping.

The pelvic fin section of each shad collected i

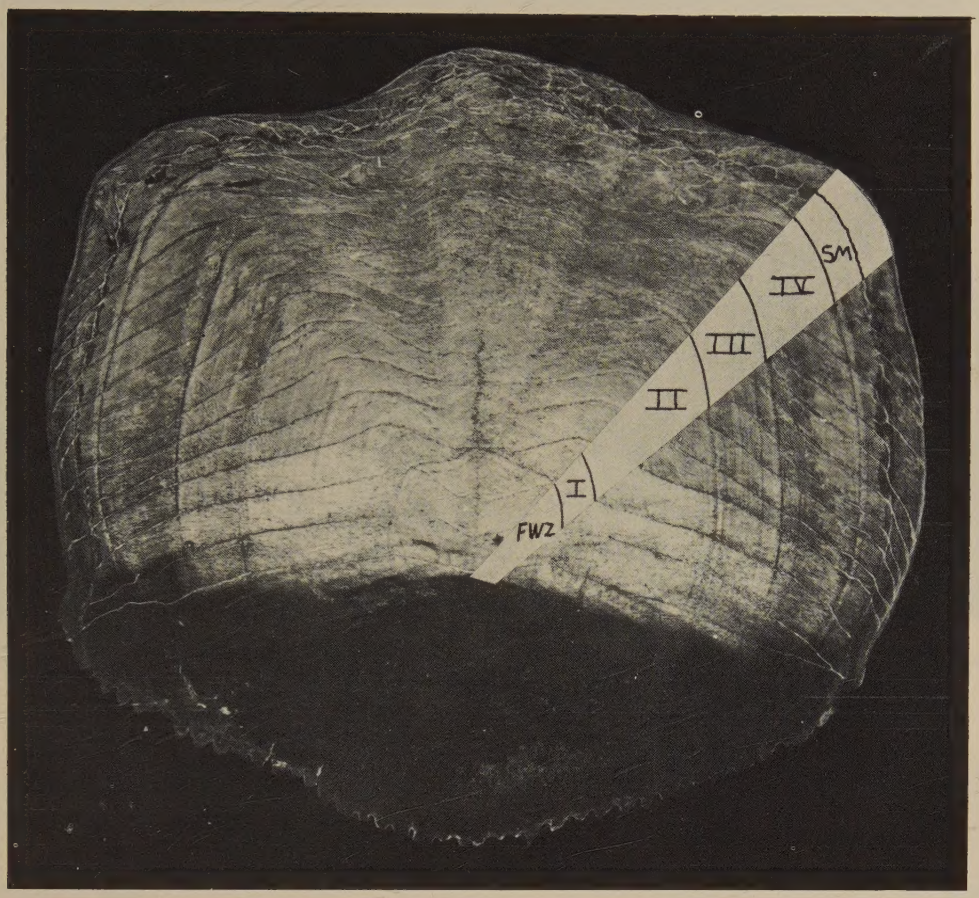

FIGURE 1.—Scale from 6-year-old shad spawning for the second time. (Roman numerals represent annuli, FWZ fresh-water zone, and SM spawning mark.)

his study was X-rayed using a method described y Sutherland (1958). Marked fins were identi-ed from radiographs by an enlargement at the istal end of the radial bones extending partially r completely across the area of separation from ne dermal fin rays (fig. 2). This method of classi-cation of marked fish is in agreement with Stuart 1958) who found from microscopic examination nat a palpable ridge was formed on marked fins t the site of cutting. Marked fins were classified ccording to the number of fin rays regenerated, egardless of the length of the rays, and placed in ne following categories: (1) no regeneration—no n rays; (2) one-third regeneration—one to three n rays; (3) two-thirds regeneration—four to six n rays; and (4) complete regeneration—seven to ine fin rays (fig. 2).

Pelvic-fin sections were classified as malformed if there was no enlargement at the distal end of the radials (fig. 3B, C). Missing fins were characterized by absence of radials or, in some specimens, absence of the entire pelvic girdle (fig. 3A, D), and absence of scar tissue at the site of fin origin. Malformed and missing fins were termed abnormal.

From a study of 28 shad collected in 1956, it was determined that 11 had abnormal pelvic fins. These included 4 males and 7 females of which 5 had malformed left or right pelvic fins and 6 had either the left, right, or both pelvic fins missing. These fish ranged in age from 3 to 6 years.

In 1957 fish with a variety of pelvic fin abnormalities were purposely collected. Of the 132 shad sampled, 62 were classified as abnormal.

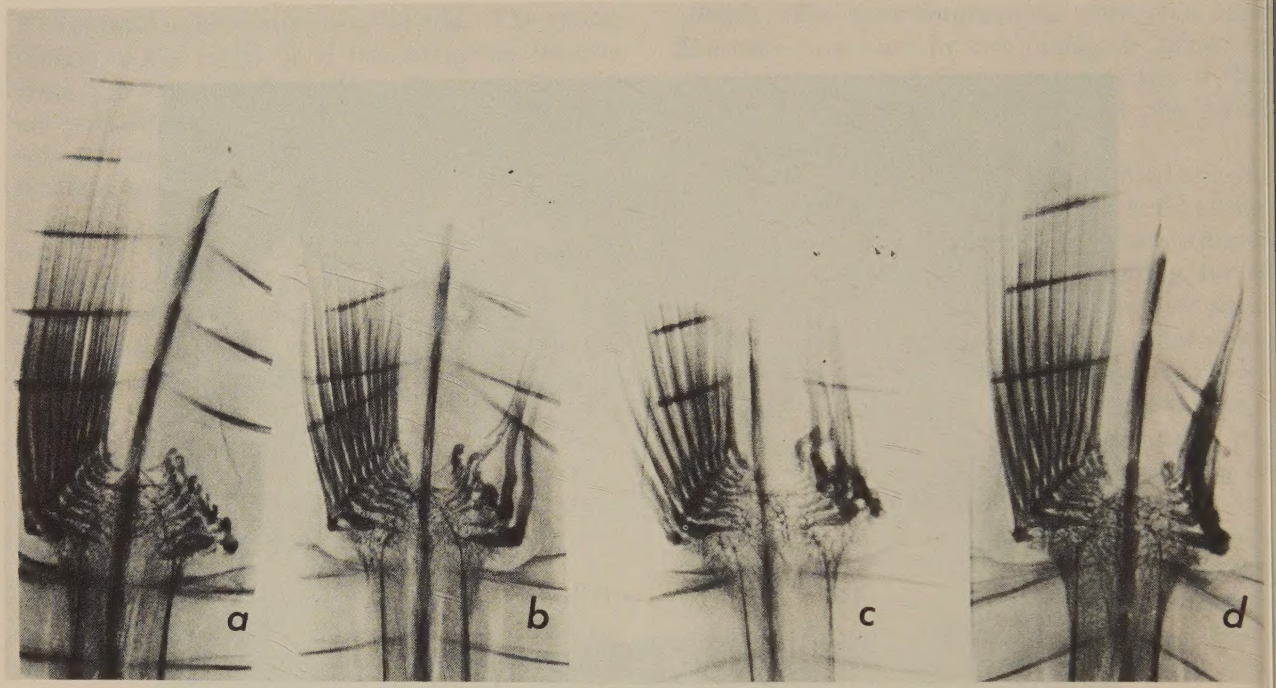

FIGURE 2.—Radiograph of pelvic fin sections from four marked shad. A—no regeneration, B—one-third, C—two-thirds, and D—complete regeneration.

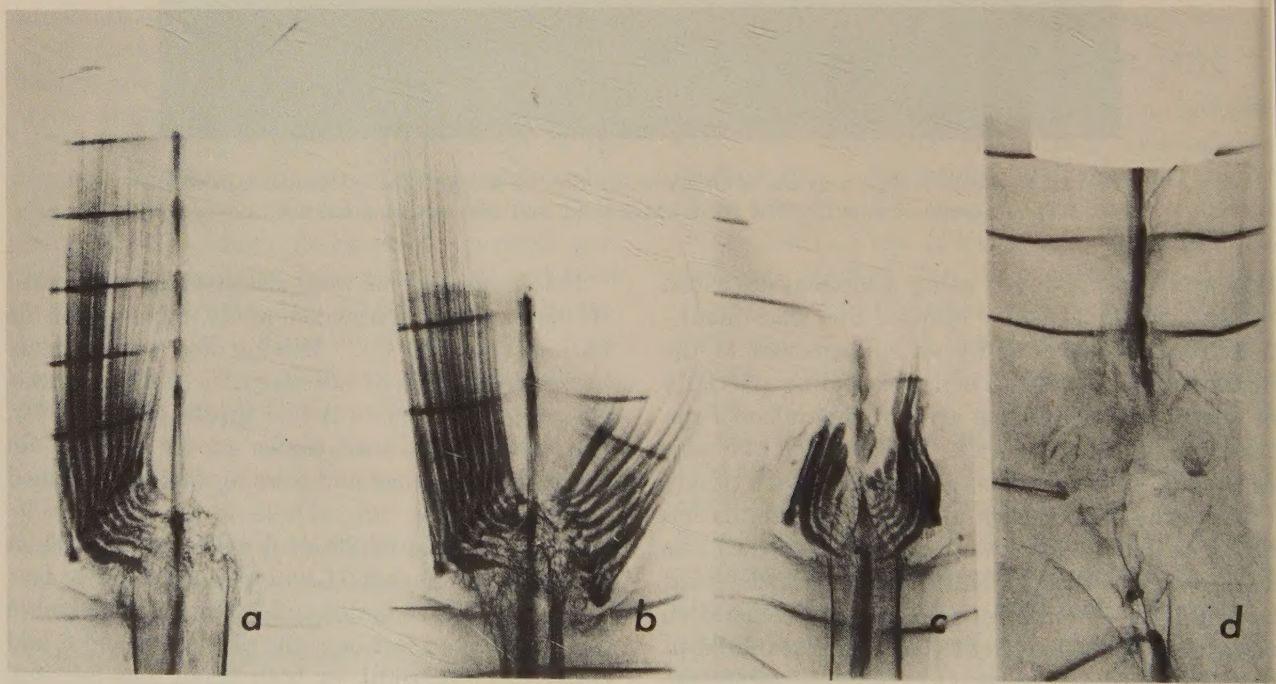

FIGURE 3.—Radiograph of pelvic fin sections from four shad with malformed and missing fins (A—right fin and radial fin supports absent, B—right fin with malformed fin rays, C—double malformation of pelvic fins, and D—pelvic girdle absent.)

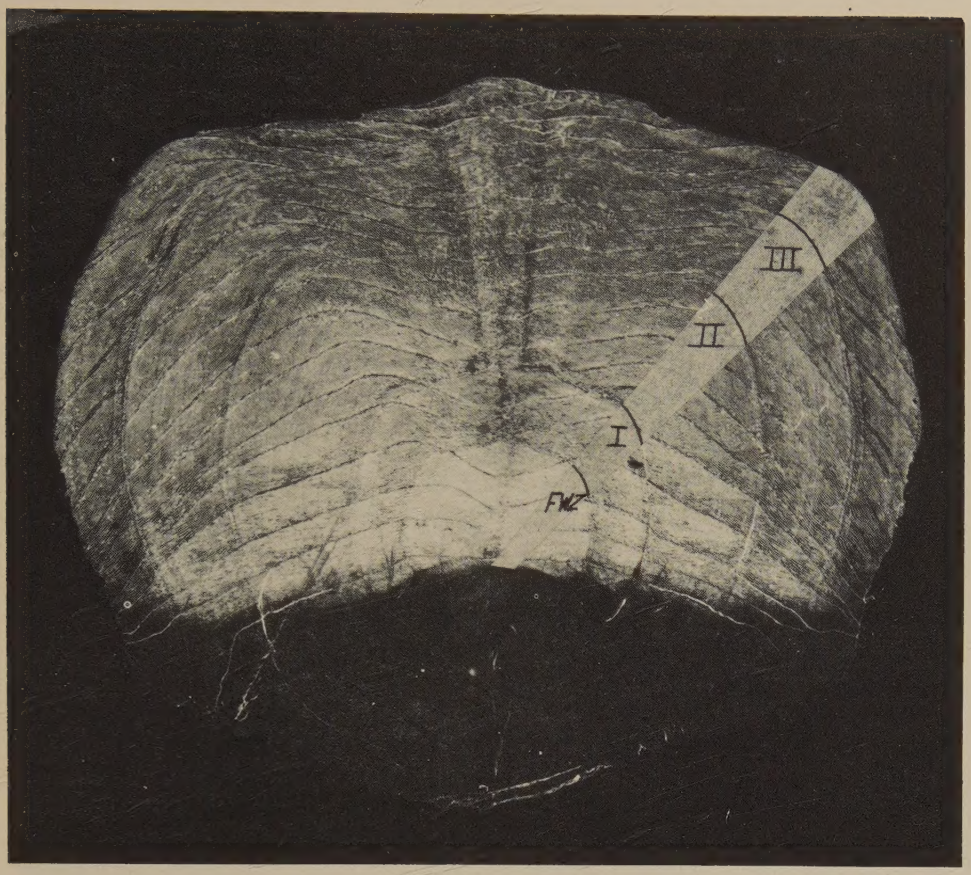

FIGURE 4.—Scale from 4-year-old marked shad spawning for the first time.

ıese included 21 males and 41 females of which had either the left, right, or both pelvic fins ılformed, and 22 had either the left, right, or th pelvic fins missing. These fish ranged in age ɔm 4 to 7 years.

Of the 57 shad collected in 1958, 18 were classi-d as abnormal. These included 9 males and 9 males of which 6 had either the left, right, or th pelvic fins malformed and 12 had either the ft, right, or both fins missing. These fish ranged age from 4 to 8 years.

MARKED FISH RECOVERED 1956

From a study of pelvic fin sections and radio-aphs it was determined that 17 marked shad ere recovered in 1956. These included 8 males d 9 females of which 3 had no regeneration of e right fin, 5 had one-third regeneration, 4 had o-thirds regeneration, and 5 had complete re-neration. Age readings indicated that all arked fish recovered were 4 years old, and spawning for the first time (fig. 4). Marked males averaged 16.4 inches, fork length, and 2.4 pounds in weight. Marked females averaged 17.9 inches, fork length, and 3.2 pounds in weight.

MARKED FISH RECOVERED 1957

From a study of pelvic fin sections and radiographs it was determined that 72 marked shad were recovered in 1957. Age determined from scale readings indicated that all but two of these fish were 5 years old. The ages of these two fish were 4 and 6 years. The radiographs and scale samples were re-examined and the above results confirmed. Therefore, on the basis of these findings, an error of approximately 3 percent exists either in interpretation of radiographs or in age determination.

The seventy 5-year-old fish that were marked included 14 males and 56 females of which 11 had no regeneration of the right pelvic fin, 18 had one-third regeneration, 26 had two-thirds re-

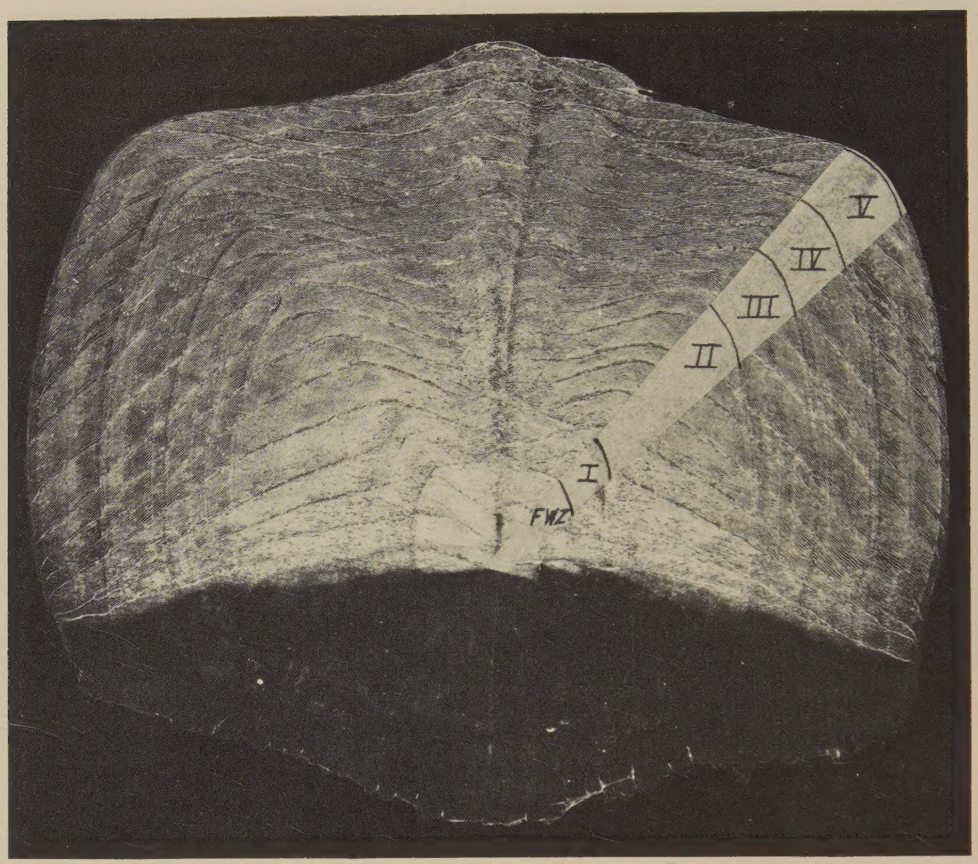

FIGURE 5.—Scale from 5-year-old marked shad spawning for the first time.

generation, and 15 had complete regeneration. This group consisted of 56 first- and 14 second-year spawners. Forty-three percent (6) of the males and 14 percent (8) of the females were spawning for the second time. Figures 5 and 6 illustrate representative scales from 5-year-old marked fish spawning for the first and second time. In figure 5 the fifth or last annulus is plainly visible, but since it was laid down just prior to the spawning migration, it is combined with the scale edge and counted as one year. Fish spawning for the second time (fig. 6) had first spawned in 1956 when 4 years old. Marked males averaged 17.6 inches fork length and 3.2 pounds in weight. Marked females averaged 18.8 inches, fork length, and 4.1 pounds in weight.

MARKED FISH RECOVERED 1958

From a study of pelvic fin sections and radiographs it was determined that 40 marked shad were recovered in 1958. Age determined from scale readings indicated that 39 fish were 6 years old and one was 5 years old. The radiographs and scale samples were re-examined and the above findings confirmed. Therefore, an error of approximately 2 percent exists either in interpretation of radiographs or in age determination.

The 39 marked recoveries included 16 males and 23 females, of which 11 had no regeneration of the right fin, 9 had one-third regeneration, 10 had two-thirds regeneration, and 9 had complete regeneration. This group consisted of 13 first-, 18 second-, and 8 third-year spawners. All males (16) and 43 percent (10) of the females had previously spawned. Sixty-two percent (10) of the males and 35 percent (8) of the females were spawning for the second year, and 38 percent (6) of the males and 9 percent (2) of the females were spawning for the third year. Figures 7 and 8 are representative scales from 6-year-old marked

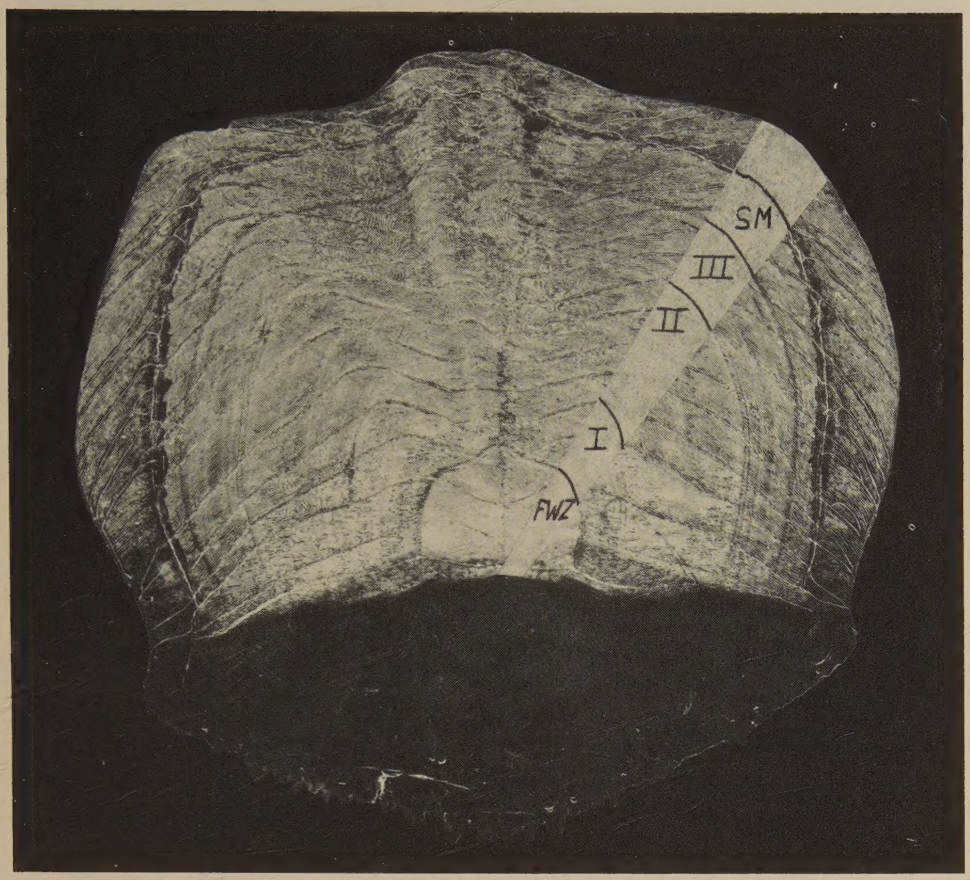

FIGURE 6.—Scale from 5-year-old marked shad spawning for the second time.

sh spawning for the first and third times.[1] Those pawning for the third time had first spawned in 956 when 4 years old. The second spawning nark was laid down in 1957. Marked males veraged 18.2 inches fork length and 3.6 pounds n weight. Marked females averaged 19.1 inches ork length and 4.5 pounds in weight.

DISCUSSION AND CONCLUSION

Of the 129 fish classified from radiographs as narked, only 3 were in disagreement with age as etermined from scale readings. These misclassi-ications, 2 in 1957 and 1 in 1958, were caused by rror either in age determination or in interpreta-ion of radiographs, which in some cases were ifficult to interpret. This minor disagreement, pproximately 2 percent of the fish classified as marked, was considered insignificant and in no way invalidates the findings of this report.

Methods used by Leim (1924), Borodin (1925), Greeley (1937), and Cating (1953), to age shad were all considered in this study. Of these methods, only Cating's proved to be a complete and valid means for determining total age, age at first spawning, and number of times previously spawned. LaPointe (1958) correctly validated the annulus as a true year mark on scales of shad spawning for the first time and he showed that Leim had mistaken the fresh-water mark for the first annulus. Therefore, the techniques used by Leim and Greeley to age shad gave age assessment 1 year greater than the actual age of the fish. Borodin's method, applied to scales of marked shad, gave erroneous results and could not be justified on the basis of the present study.

Age of marked fish collected in 1956, 1957, and 1958 as determined from scale readings, was in

[1] Figure 1 is a representative scale from a 6-year-old marked nad spawning for the second time. These fish had first spawned n 1957 when 5 years old.

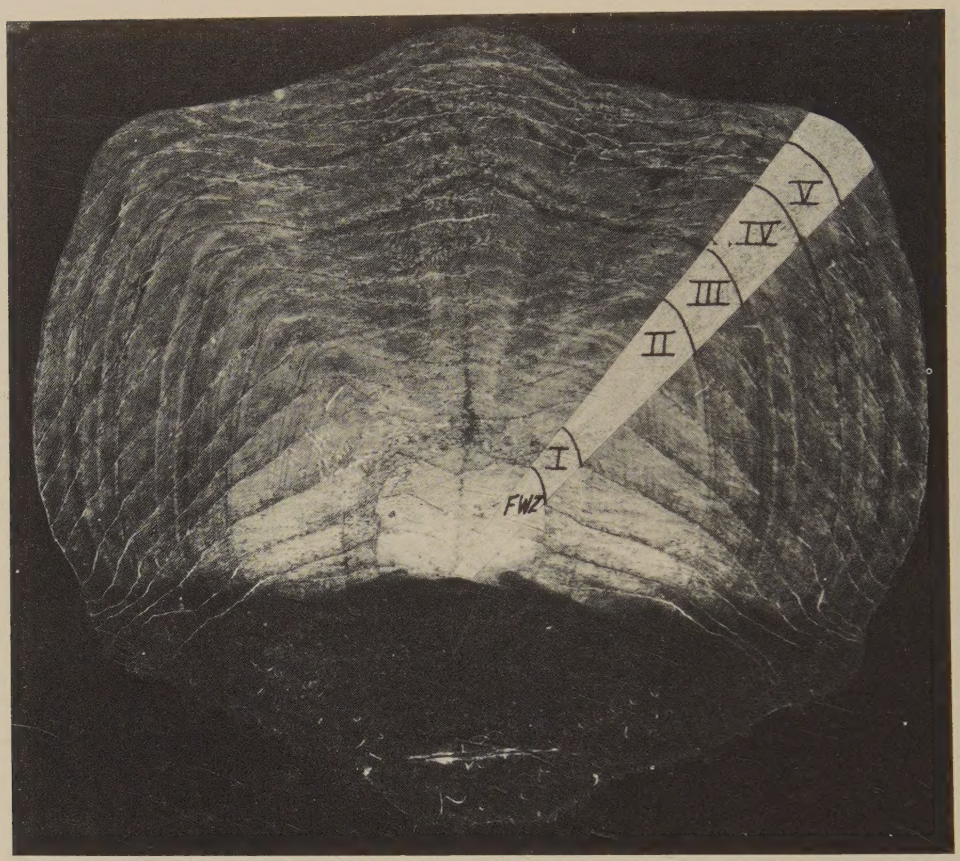

FIGURE 7.—Scale from 6-year-old marked shad spawning for the first time.

agreement with known age established by marking. These findings indicate that the method used to age shad (Cating, 1953) is valid and that annuli and spawning marks are true indicators of age.

SUMMARY

One hundred thousand juvenile shad from the Connecticut River were marked by removal of the right pelvic fin, in 1952. The objective of this program was to recover marked fish of known age in future years, to validate the use of annuli and spawning marks for determining age of shad.

Marked fish were first recovered in the Connecticut River in 1956 with subsequent recoveries in 1957 and 1958. Fish with marked and abnormal fins were collected in each of these years. Twenty-eight were collected in 1956, 132 in 1957, and 57 in 1958.

The pelvic fin section from each fish sampled was X-rayed and classified as follows: (1) marked, (2) malformed, and (3) missing. Marked fins were identified by an enlargement at the distal end of the radial bones at the point of separation from the dermal fin rays. Pelvic fin sections were classified as malformed, when there was no enlargement of the distal end of the radials. Missing fins were classified as to the fin or fins affected. The number of marked fish collected each year was determined from a study of pelvic fin sections and radiographs.

Scales from sampled shad were read for total age and number of times each fish had previously spawned. The 1956 recoveries of marked shad were 4-year-old fish spawning for the first time. Those collected in 1957 were 5-year-old fish, with recoveries divided between first and second year spawners. Fish spawning for the second time had first spawned in 1956. Marked fish collected in 1958 were 6 years old and consisted of first-, second-, and third-year spawners. Those spawning

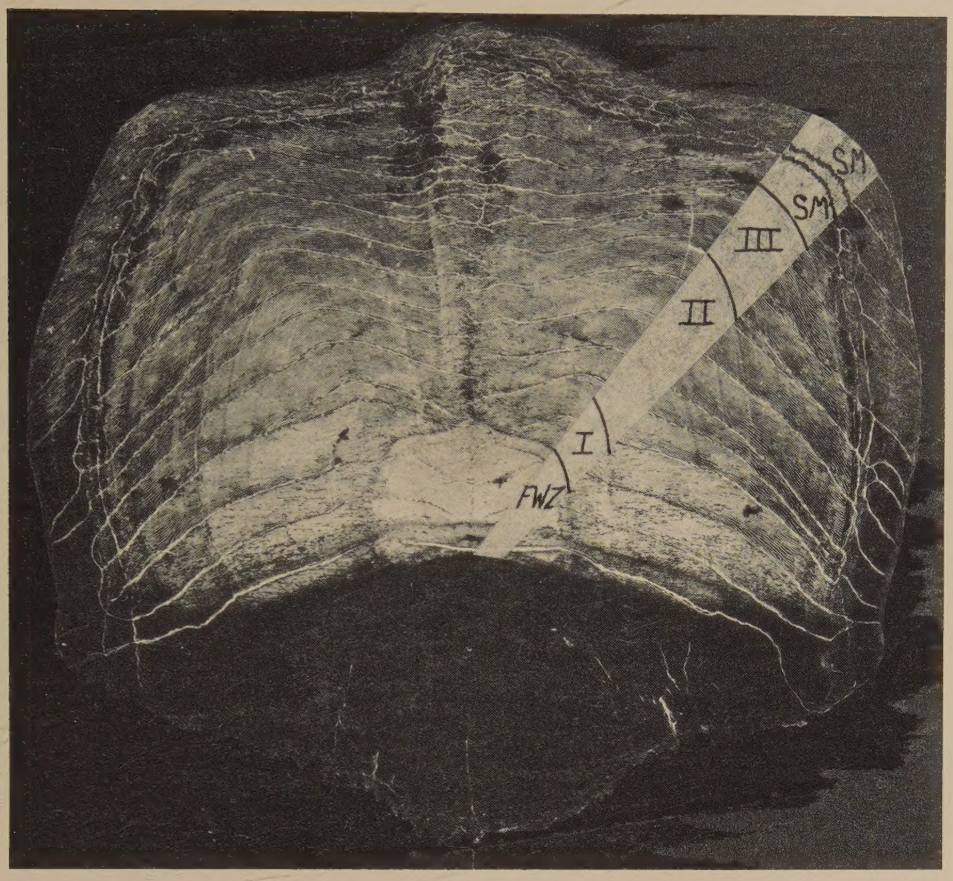

FIGURE 8.—Scale from 6-year-old marked shad spawning for the third time.

or the second time had first spawned in 1957, and nose spawning for the third time had first pawned in 1956.

Age of marked shad, as determined from scale eadings, was in agreement with known age estab- shed by marking. These findings validate the se of annuli and spawning marks for determining otal age of shad.

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